N74-10250

Paper No. 57

LARGE SOLAR BEAM TESTING AT PLANET MERCURY AND GREATER INTENSITIES IN THE JPL 25-FT SPACE SIMULATOR

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ABSTRACT

Minor modifications to the off-axis solar simulation system in the JPL 25-Ft Space Simulator have been made which allow testing at very high solar intensities over reasonably large test areas. Tests have been conducted on Mariner and Helios class spacecraft at intensities up to 7.4 solar constants with anticipation of Helios testing in early 1974 at 11 solar constants. The optical components required for these high energy solar beams can be installed or removed quickly which enhances the versatility of the facility and permits high facility utilization.

INTRODUCTION

The JPL 25-Ft Space Simulator has been in operation for solar, thermal, vacuum testing since 1962 when the first planetary mission outside earth orbit was flown. Such programs as Ranger, Surveyor, Mariner Venus, Mariner Mars, Mariner Venus/Mercury, and Viking have been tested in the simulator as well as several non-JPL projects.

The facility was originally fitted with a cassegranian solar simulator utilizing 133, 2.5KW mercury xenon compact arc lamps. This system was replaced in 1965 with an off-axis optical arrangement (Fig. 1) which uses as an energy source an array of 37, 20KW xenon arc lamps (Fig. 2). The energy from these lamps which are housed in 27-inch ellipsodial water cooled collectors passes through a 19-channel optical mixer (Fig. 3) or integrating lens unit. From the mixer the energy is projected through the penetration window onto a 23-foot collimating mirror (Fig. 4) in the top of the chamber and reflected back down into the test volume. This off-axis system is capable of producing solar intensities in excess of that at the planet Venus over a 15-foot diameter area.

High Solar Intensity Test Requirements

In order to meet the interplanetary mission objectives set forth by NASA, it was necessary to further develop the facility

*This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

capabilities to allow testing of Mariner class spacecraft at solar intensity levels in excess of that at the planet Mercury (4.8 earth constants).

With the anticipation of a Mariner Venus/Mercury (MVM73) mission to be launched in 1973, an expansion of the capabilities of the solar simulator was initiated. Because of the nature of the off-axis solar simulation system, the optical path inside the chamber had only to be intercepted at a lower elevation to concentrate the energy into a smaller but more intense solar beam. Consequently, the modification (Reference 1) did not require major changes to the system, but instead required the addition of some replaceable optical components. It was decided to provide quick-change capabilities between the existing beams required for Viking orbiter testing and the higher intensity beams needed for MVM73 (Fig. 5).

Solar System Modifications

The solar source array was not changed. Present lamp power can be increased from 20 to 25KW (limited by existing 25KW D.C. power supplies).

Two new optical mixers were built (Fig. 6) with ample water cooling to permit high energy transmission without distortion of the lens supports. One mixer was built with the proper lens arrangement to provide a 9-foot diameter beam in excess of 6.5 solar constants. The second mixer provides an 11-foot diameter beam at an excess of 4.8 solar constants.

A new 15-foot diameter collimating mirror (Fig. 7) was built and installed upon a removable support system below the existing 23-foot diameter collimator. The 15-foot mirror has a spherical curvature and is structurally similar to the 23-foot mirror.

Versatility of System

The versatility of the off-axis solar simulator is apparent in view of the variety of solar beams and intensity levels available as described in Table 1.

CURRENT AND PROJECTED SOLAR
SIMULATOR PERFORMANCE

Mixer and Beam Diameter (Feet)	Number of Lamps Available	Solar Intensity (SC) Lamps Operated at 20KW		Solar Intensity (SC) Lamps Operated at 25KW	
		Sustained, with 25% Margin	Maximum Power No Margin	Sustained, with 25% Margin	Maximum Power No Margin
SSB-15	37	1.9	2.5	2.3	2.9
SSB-15.5	37	2.2	3.0	2.8	3.5
SSB-18.5	37	1.6	2.1	2.0	2.5
SSC-9	37	7.7	10.2	9.6	12.0
SSC-11	37	4.7	6.2	5.8	7.3
SSB-8	7	1.4	1.7	1.7	2.2

1 Solar Constant = 126 w/ft^2

TABLE 1

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High Energy Test Programs

In June 1972 the MVM73 Thermal Control Model (TCM) (Fig. 9) was tested at JPL using the 9-foot diameter beam. The total operating time for the solar simulator was 576 hours at intensities from 1 solar constant to 4.8 solar constants (intensity at planet Mercury). At the highest levels operated, a margin of 25% or more was reserved for lamp degradation or failure. In July 1973, the MVM73 flight spacecraft was tested at 1, 2 and 4.8 solar constants.

The second mixer which produces an 11-foot diameter beam was built to accommodate the Helios spacecraft being built by the West German Government. It is a spin stabilized solar probe designed to fly to within 0.3 AU (Fig. 10). Its mission requirements call for testing at 11 solar constants in an 11-foot diameter beam. The Helios TCM was tested at JPL in February 1973, at intensities up to 7.4 solar constants. A test of the prototype vehicle is scheduled for April 1974 at 11 solar constants using the 9-foot diameter beam, which will necessarily but tolerably be a compromise in beam size.

System Limitations

It has been noted during high intensity test programs that the chamber penetration window temperature has become the limiting factor in further performance increases. The high intensity levels cause very high center-to-edge temperature differences. The outer edge temperature was measured using thermocouples, while the center of the window was monitored with a vacuum rated infrared radiometer. The temperature of the center of the window has attained a level of 1000°F, while the edge temperature remained at 150°F. The hoop stress produced by this gradient combined with the atmospheric pressure load has significantly reduced the safety factor such that restrictions have been placed on high power operations.

Window Contamination

It has been observed that surface contamination of the vacuum side of the penetration window is a major contributor to the measured temperature. After cleaning the window (hand polishing with cerium oxide), a reduction of as much as 200°F can be realized. This indicates that the infrared radiometer, which looks only at the surface of the window, may be measuring the effect of the contamination instead of a temperature related to the calculated internal temperature of the quartz. There may be many sources of this contamination. Diffusion pump oil, the test item, cabling, etc. Since all of these sources cannot be eliminated, procedures for monitoring window temperature and cleaning have been established for high intensity testing.

A quantity of inconsistent data collected during high intensity testing indicates that spacecraft configurations also affect the window temperature. Further studies will be required to determine the nature and significance of this effect (see Fig. 8 and Fig. 9).

Ozone Hazards

During the course of performing solar beam mapping with the chamber open, excessive levels of ozone were observed at intensities above 1 solar constant. Consideration must be given to both personnel safety and collimator mirror degradation when exposed to ozone levels above 0.25 ppm. The solar source array and the beam path external to the chamber are protected with appropriate filters which remove the ozone. Ozone levels in the building can be monitored as a protection for personnel and hardware.

SUMMARY

Recent modifications to the JPL 25-Ft Space Simulator have greatly enhanced the capability for solar simulation testing for interplanetary missions. Tests have been conducted at intensities up to 7.4 solar constants. A new penetration window which will absorb less energy than the current window, thereby reducing its operating temperature, will be installed towards the end of 1973. The facility will then be capable of performing extended tests at solar intensities up to 12 solar constants over reasonably large test areas. Highly uniform beams (±5%) are available with adequate collimation (±1° to ±2°, depending on choice of collimators) to simulate solar effects on complicated spacecraft configurations.

REFERENCE

1. Morgan, N. R. "The 7.63-Meter Space Simulator Modification" JPL TM 33-639, To Be Released.

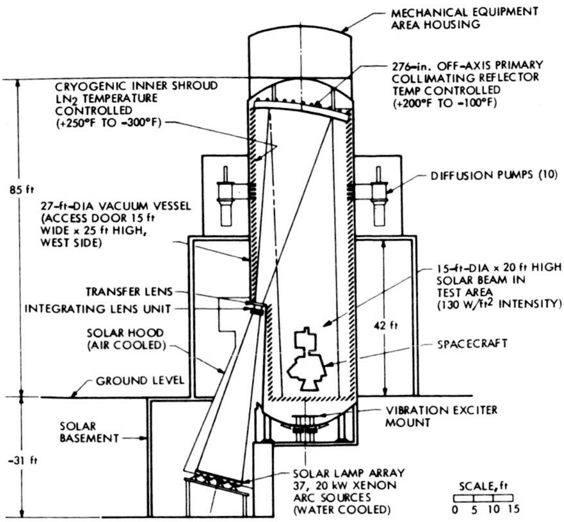

Fig. 1. JPL 25-ft space simulator

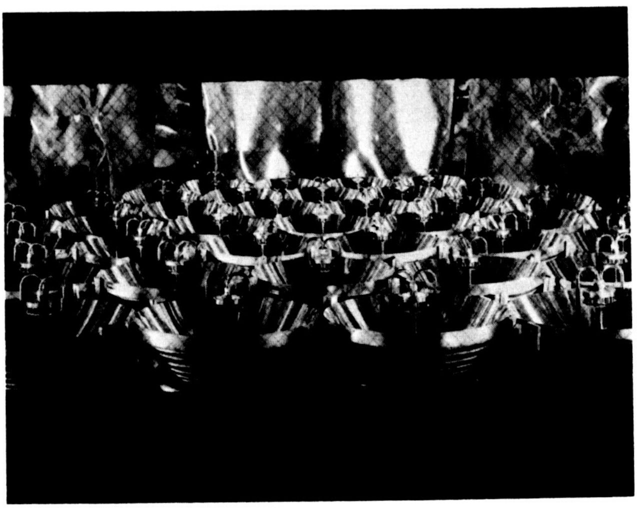

Fig. 2. Typical lamp and collector arrangement

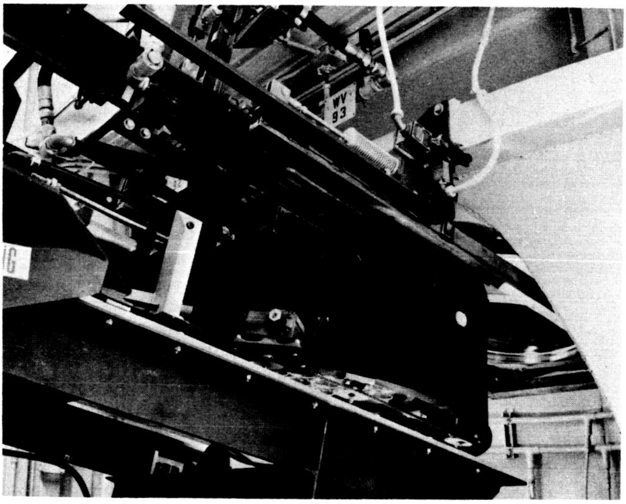

Fig. 3. Mixer lens and carriage

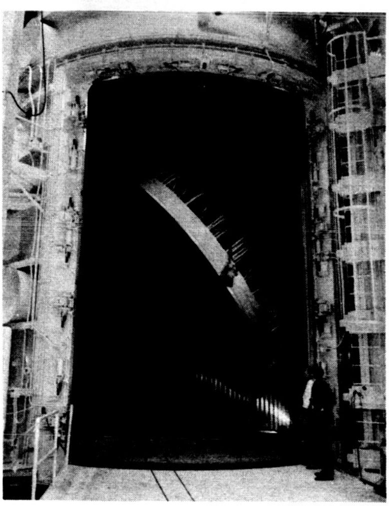

Fig. 4. JPL 23-ft mirror

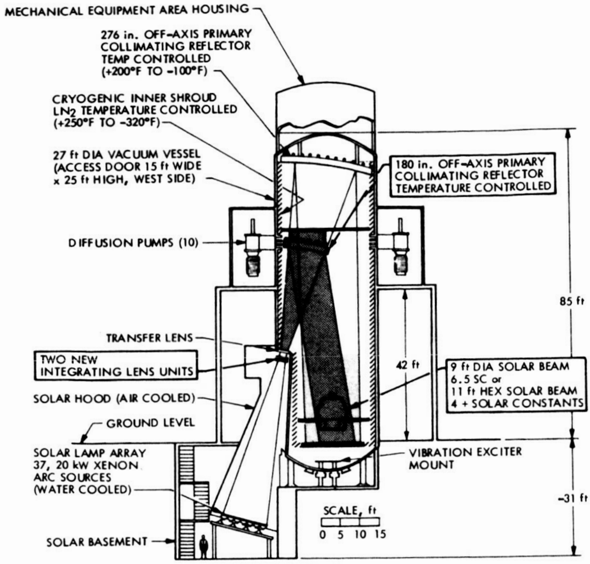

Fig. 5. JPL 25-ft space simulator cross section

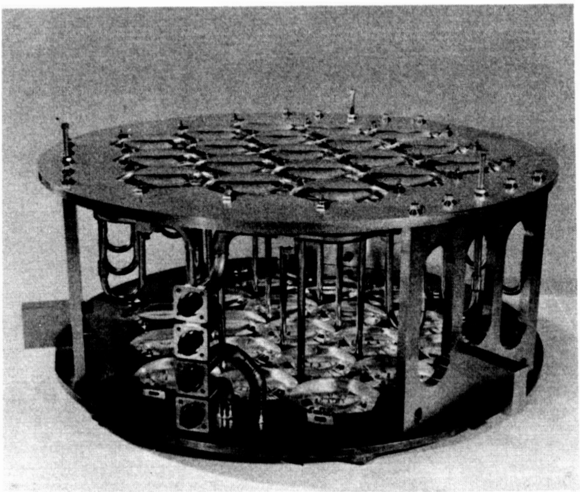

Fig. 6. Optical mixer

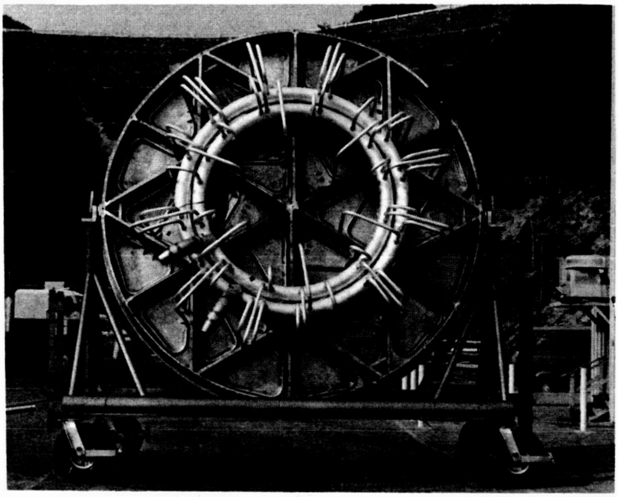

Fig. 7. JPL 15-ft collimator

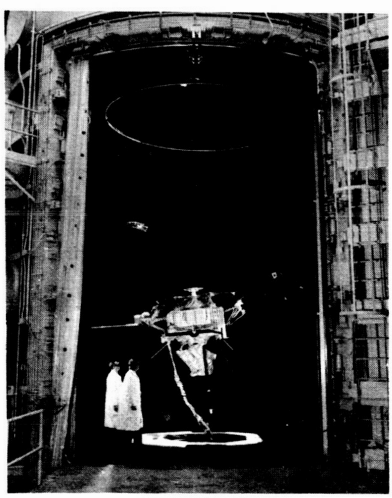

Fig. 8. MVM '73 thermal control model

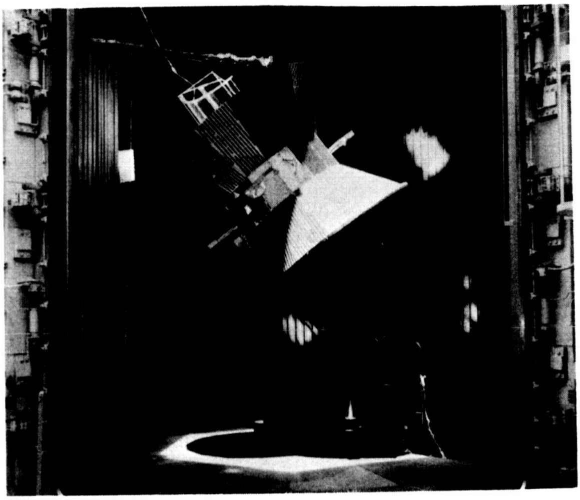

Fig. 9. Helios thermal control model